

CLAIMS

What is claimed is:

5           1.       An apparatus for producing a signal related to the concentrations of glucose and insulin,  
said apparatus comprising:

                  a first conductive composite comprising glucose oxidase and a metal posited  
within a first cylindrical tube;

10                   a second conductive composite comprising a metal oxide catalyst posited within  
a second cylindrical tube;

                  a sleeve containing the first cylindrical tube and the second cylindrical tube;  
                  a first electrical contact within the first cylindrical tube in contact with the first  
conductive composite; and

15                   a second electrical contact within the second cylindrical tube in contact with the  
second conductive composite.

                  2.       The apparatus of claim 1 wherein the first conductive composite comprises a carbon  
powder conductor.

20           3.       The apparatus of claim 1 wherein the metal comprises at least one metal selected from  
the group consisting of rhodium, iridium, and ruthenium.

                  4.       The apparatus of claim 1 wherein the sleeve comprises a conductor.

25           5.       The apparatus of claim 4, further comprising an insulating layer posited on the exterior  
the sleeve and a conducting layer posited on the insulating layer.

                  6.       The apparatus of claim 1 wherein the metal oxide catalyst comprises at least one  
member selected from the group consisting of  $\text{RuO}_x$  and  $\text{IrO}_x$ .

7. The apparatus of claim 1 wherein the first cylindrical tube and the second cylindrical tube comprise an interior diameter of less than 500  $\mu\text{m}$ .

5 8. The apparatus of claim 1 wherein the first conductive composite comprises an oxygen-rich binder.

9. The apparatus of claim 8 wherein the oxygen-rich binder comprises at least one compound selected from the group consisting of perfluorochemical, myoglobin, and hemoglobin.

10 10. The apparatus of claim 9 wherein the perfluorochemical comprises polychlorotrifluoroethylene.

11. An apparatus for producing a signal related to the concentration of a substance, said apparatus comprising:

15 a conductive composite comprising an oxygen-dependent enzyme and sufficient oxygen-rich binder to support an oxygen-dependent enzymatic reaction in the absence of exogenous oxygen;

a sleeve with a first end and second end;

20 a cavity disposed within the first end of said sleeve wherein the length of the sleeve is at least about 0.2 mm, said cavity containing said composite and forming an electrode end of said composite at the first end of said sleeve; and

an electrical contact disposed within the second end of said sleeve extending into said cavity;

25 wherein the ratio of the surface area of the electrode end of said composite to the volume of said composite is at least about 1:8.

12. The apparatus of claim 11 wherein said conductive composite comprises a metal powder conductor.

13. The apparatus of claim 11 wherein said conductive composite comprises a carbon powder conductor.

5 14. The apparatus of claim 13 wherein said carbon powder comprises a metalized graphite.

15. The apparatus of claim 14 wherein said metalized graphite comprises at least one metal selected from the group consisting of rhodium, iridium, and ruthenium.

10 16. The apparatus of claim 11 wherein the sleeve comprises an insulator.

17. The apparatus of claim 16 wherein said insulator comprises polytetrafluoroethylene.

15 18. The apparatus of claim 11 wherein said cavity comprises a diameter of between approximately 0.2 mm and approximately 5.0 mm.

19. The apparatus of claim 18 wherein said cavity comprises a diameter of 2.0 mm.

20 20. The apparatus of claim 11 wherein said oxygen-rich binder comprises at least one compound selected from the group consisting of perfluorochemical, myoglobin, and hemoglobin.

21. The apparatus of claim 20 wherein said perfluorochemical comprises polychlorotrifluoroethylene.

25 22. The apparatus of claim 11 wherein said oxygen-dependent enzyme comprises an oxidase enzyme.

23. The apparatus of claim 11 wherein said oxygen-dependent enzyme comprises glucose oxidase.

24. The apparatus of claim 11 further comprising a protective membrane covering at least a portion of the electrode end conductive composite.

5 25. The apparatus of claim 24 wherein said membrane comprises at least one compound selected from the group consisting of polyurethane, polycarbonate, polyethylene glycol, polyvinyl chloride and polyhydroethylmethacrylate.

10 26. The apparatus of claim 24 wherein said membrane comprises an oxygen-rich film.

27. The apparatus of claim 26 wherein said film comprises at least one compound selected from the group consisting of Pluronic F-68 and a perfluorosulfonate isomer.

15 28. The apparatus of claim 11 wherein said sleeve comprises a needle.

29. A method of simultaneous detection of glucose and insulin in a liquid sample, the method comprising the following steps:

- 20
- a) providing a first biosensor comprising glucose oxidase;
  - b) providing a second biosensor comprising a metal oxide catalyst;
  - c) simultaneously placing the first biosensor and the second biosensor in the liquid sample;
  - d) applying a detection potential to the first biosensor and the second biosensor;
  - e) detecting a biocatalytic signal at the first biosensor; and
  - f) detecting an electrocatalytic signal at the second biosensor.

25 30. The method of claim 29 wherein detecting comprises amperometric detection.

31. The method of claim 29 wherein detecting comprises stripping potentiometry.

32. The method of claim 29 wherein the metal oxide catalyst comprises at least one member selected from the group consisting of  $\text{RuO}_x$  and  $\text{IrO}_x$ .

33. The method of claim 29, wherein the first biosensor comprises an oxygen-rich binder.

34. A method of detecting substrate concentration of an environment using a composite biosensor, the method comprising the following steps:

a) providing a biosensor comprising a conductive composite comprising sufficient oxygen-rich binder to support an oxygen-dependent enzymatic reaction in the absence of exogenous oxygen, a conductor, an oxygen-dependent enzyme, a reservoir containing the composite, and an electrode end of the composite, wherein the ratio of the surface area of the electrode end of said composite to the volume of said composite is at least about 1:8,

b) placing the biosensor in the environment, and

c) detecting the substrate concentration.

35. The method of claim 34 wherein the step of providing a biosensor comprises providing a biosensor comprising a metal powder conductor.

36. The method of claim 34 wherein the step of providing a biosensor comprises providing a biosensor comprising a carbon powder conductor.

37. The method of claim 36 wherein the step of providing a biosensor comprises providing a biosensor comprising a metalized graphite.

38. The method of claim 37 wherein the step of providing a biosensor comprises providing a biosensor comprising at least one metal selected from the group consisting of rhodium, iridium, and ruthenium.

39. The method of claim 34 wherein the step of providing a biosensor comprises providing a biosensor comprising at least one oxygen-rich binder compound selected from the group consisting of perfluorochemical, myoglobin, and hemoglobin.

5 40. The method of claim 34 wherein the step of providing a biosensor comprises providing a biosensor comprising a cylindrical reservoir with a diameter of between approximately 0.2 mm and approximately 5.0 mm.

10 41. The method of claim 34 wherein the step of providing a biosensor comprises providing a biosensor comprising an oxidase enzyme.

42. The method of claim 34 wherein the step of providing a biosensor further comprises providing a biosensor comprising a sleeve.

15 43. The method of claim 34 wherein the step of placing the biosensor in the environment comprises placing the biosensor in an *in vivo* environment.

44. The method of claim 34 wherein the step of placing the biosensor in the environment comprises placing the biosensor in an *ex vivo* clinical environment.

20 45. The method of claim 34 wherein the step of placing the biosensor in the environment comprises placing the biosensor in an industrial environment.

25 46. The method of claim 34 wherein the step of detecting the substrate concentration comprises detecting an inhibitor concentration.

47. The method of claim 34 wherein the step of detecting the substrate concentration comprises detecting the substrate concentration comprising approximately 1.0  $\mu$ mol - 0.2 molar concentration.

48. The method of claim 34 wherein the step of detecting the substrate concentration comprises detecting at least one substance selected from the group consisting of glucose, lactate, and cholesterol.